Neurocognitive and Temperamental Systems of Self-Regulation and Early Adolescents' Social and Academic Outcomes

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ABSTRACT—The aim of the current study was to examine the role of individual differences in neurocognitive and temperamental systems of self-regulation in early adolescents' social and academic competence. Measures used in the study included the Attention Network Test, the Early Adolescence Temperament Questionnaire, a peer-reported Social Status Questionnaire, a self-reported measure of Schooling Skills, and information on grades obtained by the students in a variety of school subjects (n = 69 12-year olds). Results showed that efficiency of the neurocognitive network of executive attention is related to academic outcomes, particularly in mathematics, as well as to aspects of social adjustment. Temperamental effortful control appears to be a significant predictor of all dimensions of school competence assessed in this study and mediates the relationship between social adjustment and poor schooling outcomes. These data suggest that individual differences in systems of self-regulation are central to understanding processes of learning and social adjustment in the school.

Selecting information and controlling thoughts and actions have been a major function of attention from the earliest theoretical models (James, 1890). Individual differences in attentional control and temperamental characteristics related to volitional regulation of feelings and actions largely contribute to the ability to accomplishing goals, following instructions, and complying with social norms.

Data have supported the presence of three brain networks related to different aspects of attention. These networks carry out the functions of alerting, orienting, and executive control (Posner, Rueda, & Kanske, 2007). Alerting is defined as achieving and maintaining a state of high sensitivity to incoming stimuli and has been associated with frontal and parietal regions of the right hemisphere. Orienting refers to the selection of information from sensory input. The orienting system for visual events has been associated with posterior brain areas, including the superior parietal lobe, the temporal parietal junction, and the frontal eye fields. Finally, executive attention involves the mechanisms for consciously monitoring and resolving conflict among thoughts, feelings, and responses. It is related to action coordination in novel or dangerous situations, detecting and correcting errors, and overcoming habitual (or automatic) responses (Posner & DiGirolamo, 1998). The brain network associated with this function includes the anterior cingulate cortex (ACC) and lateral prefrontal cortex.

The executive attention network is the most directly involved in cognitive and affective regulation (Bush, Luu, & Posner, 2000). One of the main nodes of the executive attention network, the anterior cingulate gyrus, is consistently activated by situations requiring the regulation of induced emotions (Beauregard, Levesque, & Bourgoulin, 2001; Ochsner, Bunge, Gross, & Gabrieli, 2002). Moreover, the extent of activation of the executive network has been related to regulation of memory processes (Anderson et al., 2004) and other cognitive demands such as perception, response

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selection, working memory, and problem solving (Duncan & Owen, 2000).

Understanding individual differences in the efficiency of self-regulation from infancy to adulthood has been undertaken in studies of temperament. Temperament is defined as constitutionally based individual differences in reactivity and regulation in emotion, activity, and attention (Rothbart & Bates, 2006). Research in the past years has come to identify three broad dimensions that characterize temperament during childhood and adolescence (Rothbart, 2007; Rothbart & Bates, 2006), namely, Extraversion/Surgency (E/S), Negative Affect (NA), and Effortful Control (EC). The first two dimensions describe individual differences in approach/avoidance reactivity, respectively. The third dimension describes individual differences in attentional control and the flexible regulation of behavior, such as choosing a particular action under conflicting conditions, detecting errors, and planning (Rothbart & Rueda, 2005). Reactive temperament has been related to functioning of the amygdala and dopamine systems, respectively, for NA and E/S (Rothbart & Posner, 2006), whereas the executive attention network is viewed as the neural substrate supporting EC (Rothbart & Rueda, 2005; Rueda, Posner, & Rothbart, 2005).

The concepts of executive attention and EC represent different levels of analysis of the ability to exercise control over one's behavior (Rothbart & Rueda, 2005; Rueda, Posner, & Rothbart, 2004). Executive attention is a concept emerging from the neurocognitive literature and is linked to the control of cognition and cognitive flexibility; whereas EC is a concept developed within the literature on temperament and it is related to the regulation of reactivity systems associated with positive/approaching and negative/avoiding responses. Several studies have consistently shown a correlation between performance in conflict tasks tapping executive attention, such as Stroop-like and flanker tasks, and parent- and self-reported measures of EC (Rueda, Posner et al., 2004). Thus, together with their conceptual overlap, the empirical correlation supports the idea of these two concepts as representing different dimensions of a system involved in self-regulation.

Both reactive and regulative systems, as well as the interactions between them, are involved in socialization and socioemotional regulation. For instance, during childhood, EC appears to be negatively associated with the incidence of externalizing behavioral problems, which are characterized by high levels of aggression and impulsivity, after controlling for other cognitive and social risk factors (Olson, Sameroff, Kerr, Lopez, & Wellman, 2005; Valiente et al., 2003). In addition, preadolescents with and without behavioral problems appear to have different temperamental profiles. Individuals exhibiting externalizing problems show higher scores on E/S and frustration and lower rates of EC, while individuals showing internalizing problems are high on fear and shyness and moderately low on EC (Oldehinkel, Hartman, De Winter, Veenstra, & Ormel, 2004). Other studies have also shown that both mother and self-reported low EC together with poor efficiency of executive attention appear to be consistent predictors of behavior problems during adolescence (Ellis, Rothbart, & Posner, 2004).

The ways in which children differ from one another affect their willingness to explore and learn as well as their discouragement, frustration, and avoidance of potential sources of knowledge (Rothbart & Jones, 1998). Hence, due to variations in reactivity and attentional control, children may differ in their adjustment to the requirements and challenges of the educational setting. In turn, this adjustment process seems to influence more specific aspects of social development such as self-esteem and relationships with peers, parents, and teachers (Sanson, Hemphill, & Smart, 2004).

Negative emotionality and low EC have been consistently linked to problems with adjustment at school from a young age (Nelson, Martin, Hodge, Havill, & Kamphaus, 1999). Teacher-rated higher levels of aggression and anxiety in kindergarten are related to poorer achievement through a relation with lack of cognitive self-control in school tasks (Normandeau & Guay, 1998). Moreover, measures of EC in children show a positive association with academic outcomes, especially mathematics (Blair & Razza, 2007).

The role of attention in cognitive and affective regulation suggests that this function would also be a relevant contributor to school competence. In line with this, measures tapping the executive attention network, such as Stroop-like interference and performance on inhibitory control tasks, also show a consistent relationship with arithmetic competency (Blair & Razza, 2007; Bull & Scerif, 2001; Espy et al., 2004). In addition, there is some evidence indicating that children's attention is associated with adjustment to the school context (Raver, Blackburn, Bancroft, & Torp, 1999). Eisenberg, Guthrie, and colleagues (1997) also found an association between teachers' and parents' reports of elementary school children attentional control and peer nominations for social status.

The current study aims at examining the interrelations between efficiency of attentional networks and temperament in early adolescents, and to determine the contribution of the different cognitive and temperamental systems to social and academic aspects of school competence during that age period. Figure 1 presents an overview of the attentional and temperamental measures taken into account and their hypothesized relationship to the various dimensions of school competence considered in the current study. Given the central role of systems of EC and executive attention on self-regulation, we expected these two measures to be the strongest predictors of social adjustment and academic performance. Moreover, considering prior evidence suggesting that processes of peer rejection lead to decreases in classroom participation and to lower rates of achievement in childhood (Buhs, Ladd, & Herald, 2006), we expected peer reported evaluations of social status to be related to academic competence in our study. However, we also anticipated individual differences

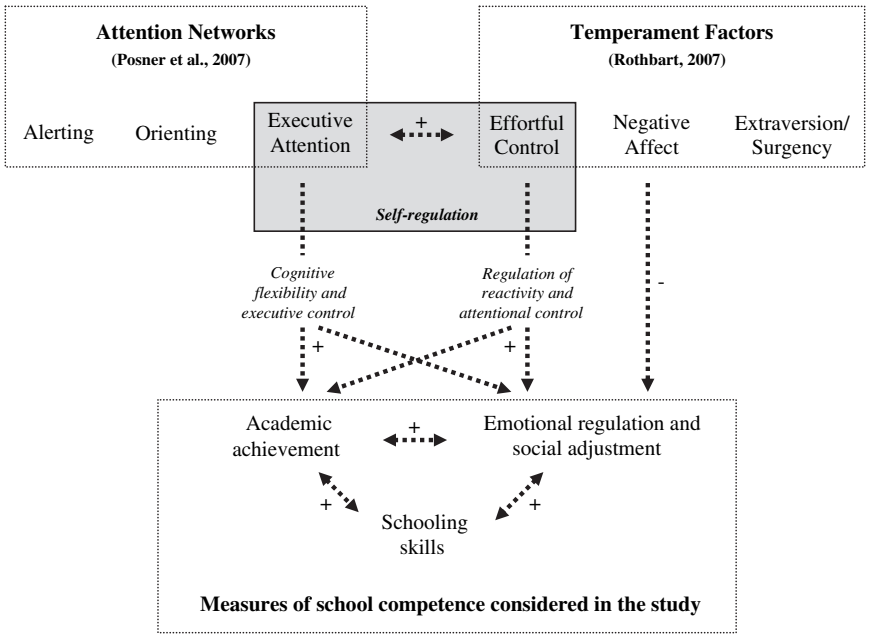

Fig. 1. Overview of the attention and temperament measures assessed in the current study and their hypothesized relationships with academic achievement, socioemotional adjustment at the school, and schooling skills.

in self-regulation to play an important role in the association between maladjustment and competence at school.

METHOD

Participants

Sixty-nine children (mean age: 12.7 years, *SD*: 0.65; 34 boys) enrolled at Padre Manjón High School in Granada (Spain) and their parents participated in the study. Participants were recruited through a mailed letter addressed to their families. The caregivers of all participants gave written consent to be involved in the study. All participants except three were Caucasian-European.

Procedure

Participants completed questionnaires on temperament, schooling skills, and social status individually while in class in two separate 50-min sessions. In a third session, children performed the Attention Network Test (ANT). This task was administered at the school simultaneously for groups of 10–12 children. The instructions to complete the task were given collectively and then the task was completed individually by each child in a computer assigned to him/her with sufficient separation between participants. The parent-report version of the temperament questionnaire was sent to the parents with instructions for completing it and returning it to the school in a sealed envelope. Finally, the high school board provided information on grades obtained at the end of the academic year.

Measures

Attention Network Task

A modified version of the Fan et al. (2002) adult ANT was used.[1] Information on the procedure of this task is provided in Figure 2. Completion of the task allows calculation of three scores related to the efficiency of the attention networks. The *alerting score* provides a measure of the benefit in performance by having a signal that informs about the immediate upcoming of the target and using this information to get ready to respond. The *orienting score* provides a measure of how much benefit is obtained in responding when information is given about the location of the upcoming target. Finally, the *executive attention score* indicates the amount of interference experienced in performing the task when stimulation conflicting with the target is presented in the display. Larger interference scores indicate less efficiency of conflict resolution mechanisms (executive attention).

Temperament Questionnaires

Self-report and parent-report versions of the Early Adolescence Temperament Questionnaire-Revised (EATQ-R; Ellis and Rothbarth, 2001) translated into Spanish were used to measure children's temperament. These questionnaires contain 65 items (self-report) or 62 items (parent-report) describing adolescents' behavior in a variety of everyday life situations. Participants' answers indicated the extent to which each item applied either to them (self-report) or their child (parent-report). The EATQ-R collects information about four broad factors of children's temperament: EC, E/S, NA and Affiliation

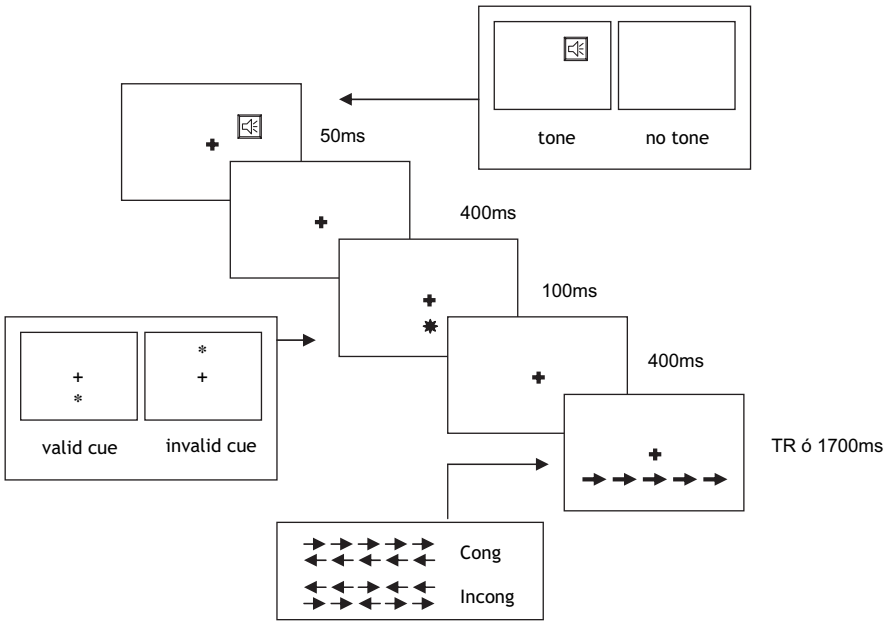

Fig. 2. Schematic representation of the Attention Network Test (ANT). Each trial starts with the presentation of a fixation cross lasting between 400 and 1600 ms. Then, an auditory tone of 2,000 Hz (alerting cue) in half the trials during 50 ms (no tone was presented in the other half). After a blank interval of 400 ms, an orienting cue consisting of an asterisk is presented in two-thirds of the trials for 50 ms (in the other one-third of the trials no cue was presented). Finally, a target stimulus is presented consisting of an arrow pointing either right or left. The target is flanked by two arrows on each side. The flanking arrows may point in the same direction as the target arrow (congruent trials), or in the opposite direction (incongruent trials), equally often. The target appears either above or below the fixation point. When presented, the orienting cue appears with equal probability either at the same location as the target (cued trials) or at the opposite location (uncued trials). Participants are instructed to discriminate the direction of a target arrow by pressing a corresponding key, left or right, in the computer's keyboard as rapidly and accurately as possible, while both reaction time (RT) and accuracy of the response are registered. *Note.* Alerting score = median RT to no tone trials – median RT to tone trials; Orienting score = median RT to trials with invalid cue – median RT to trials with valid cue; Executive Attention score = median RT to incongruent trials – median RT to congruent trials.

(AF). The scales loading on the factor EC are Activation Control, Attention, and Inhibitory Control. The scales loading on the E/S factor are High-intensity Pleasure, Fear and Shyness, the last two loading negatively. Aggression, Depressive Mood, and Frustration, load on the NA factor. Finally, the AF factor is equivalent to the AF scale in the parent-report version. AF, Perceptual Sensitivity and Pleasure Sensitivity load on the AF factor in the self-report version. The internal reliability (measured by Cronbach's alpha) of the EATQ-R factors calculated in our sample were: EC, α = .84; AF, α = .73; E/S, α = .42: NA, α = .63, for the parent-report questionnaire; and EC, α = .71; AF, α = .41; E/S, α = 52.; NA, α = .51, for the self-report measure.

Schooling Skills

Information on schooling skills was obtained from each participant using the student-report version of the Health Resources Inventory (HRI; Juvonen and Keogh, 1992). The HRI consists of 31 items which group onto four factors: Rules Following (RF; Cronbach's α = .80), Student-role Understanding (SrU; α = .76), Sociability (SO; α = .64) and Tolerance to Frustration (TF; α = .60). The RF factor reflects the student ability to function within the constraints of the school environment (e.g., "I am well-behaved in school"). The SrU factor describes behavior associated with effective learning such as individuals' understanding of the duties and responsibilities of students (e.g., "I am interested in school work"). The SO factor consists of items reflecting effective interpersonal functioning (e.g., "My classmates are fond of me"). The factor TF measures the individual ability to cope with failure and other social pressures (e.g., "I can accept things not going my way"). All items are responded on a 5-point Likert scale ranging from *never* to *always*.

Peer-Reported Social Status

Information about social status was obtained for each participant using a peer-report questionnaire containing six questions. The first four questions are about naming three classmates who are (1) good to work with, (2) not good to work with, (3) good to spend free time with, and (4) not good

to spend free time with. In question 5, students are asked to name classmates (one nomination per statement) who are characterized by a series of statements including (a) having a lot of friends; (b) not having a lot of friends; (c) having a good relationship with teachers; (d) not having a good relationship with teachers; (e) being a nice classmate; (f) not being a nice classmate; (g) being able to pay attention and listen to others; (h) often calling others attention; (i) having skills to solve social conflicts; (j) being aggressive; (k) having communication skills; (l) having troubles in communicating with others; (m) sharing his/her success with others; and (n) being an envious person. The factorial analysis of question 5 provided three different factors. The first factor, which accounted for 29.5% of the variance, was called "Appreciated" because all the items loading on it (a, c, e, g, i, and k; $\alpha = .85$) were about positive social evaluations. A second factor that explained 16% of the variance was labeled "Rejected" because the items loading on it (b, f, and n; $\alpha = .75$) implied a lack of social acceptation from peers. The third factor, which explained the 19% of the variance, was called "Unsocial" because it involved items related to behaviors that were not socially valued (d, j, h, and l; $\alpha = .94$). Finally, in the last question of the Social Status Questionnaire, children rated how they got along with their classmates scoring each of them from 1 (*very well*) to 5 (*very bad*).

Academic Outcomes

The high school board provided information on grades obtained at the end of the academic year by each student (see Table 1).

Missing Data

The valid *n* for each measure is provided in Table 1. Sixteen parents refused to complete the temperament questionnaire. Two children did not complete the HRI questionnaire because

Table 1
Descriptive Statistics on all Measures

		Valid n	*Mean*	*Min*	*Max*	*SD*
Attention	Alerting (AL_{RT})	67	14.5	−0.41	78	223
(ANT scores)	Orienting (OR_{RT})	67	63.7	−3.5	157.5	27.7
	Executive attention (EX_{RT})	67	107	20	317.5	46
	Executive attention (% errors; EXERR)	67	4.8	−1	48	7.7
Temperament	Effortful control (EC_S)	69	3.6	2.5	4.9	0.6
(EATQ self	Extraversion/Surgency (E/S_S)	69	3.6	1.97	4.8	0.6
report)	Negative Affect (NA_S)	69	2.7	1.4	3.6	0.5
Temperament	Effortful Control (EC_P)	53	3.3	1.7	4.86	0.67
(EATQ parent	Affiliation (AF_P)	53	2.75	1.8	3.9	0.46
report)	Negative Affect (NA_P)	53	2.98	2.3	3.6	0.34
Schooling skills	Rules Following (RF)	67	3.9	2.2	4.9	0.61
(HRI self report)	Student-role Understanding (SrU)	67	4.1	2.4	5	0.59
	Sociability (SO)	67	4.3	2.4	5	0.61
	Tolerance to Frustration (TF)	67	3.8	2.2	5	0.68
Academic achievement	Nature science (NS)	69	5.8	1.5	10	2.3
(grades)	Social science (SS)	69	5.8	1	10	2.3
	Physical education (PE)	69	5.7	2.5	9.5	1.6
	Native language (NL)	69	6.1	2	9.5	1.8
	Foreign language (FL)	69	5.9	1	10	2.1
	Mathematics (MA)	69	5.7	1.5	9	1.9
	Music (MU)	69	5.8	1	10	2.3
	Technology/mechanical science (TM)	69	5.7	0.5	9.5	2.1
Social status	Good to work with (GW)	46	3	0	8	2.2
(peer reported)	Not good to work with (NGW)	46	3.1	0	21	3.7
	Good to spend free time with (GFT)	46	2.6	0	10	2
	Not good to spend free time with (NGFT)	46	2.5	0	20	3.7
	Appreciated (AP)	46	0.77	0	7.3	1.1
	Rejected (RJ)	46	0.60	0	10.3	1.8
	Unsocial (US)	46	0.60	0	8.7	1.3
	Mean score of social appreciation (mSA)	45	4.23	1.57	3.26	0.66

Note. ANT scores are expressed in milliseconds. Between parentheses appear the abbreviations of the variables names that will be used in subsequent tables and figures.

they were absent during the testing session. Finally, only 46 families consented to their child completing the Peer-Reported Social Status questionnaire.

RESULTS

Descriptive statistics on all measures are presented in Table 1.

Analysis of the ANT

Data from two children were not included in the analysis of this task due to technical problems during task completion. Separate 2 (alerting tone vs. no tone) × 2 (orienting valid cued vs. invalid cued) × 2 (executive attention congruent vs. incongruent) repeated measures analysis of variance (ANOVA) were conducted with the mean of median RTs and percentage of errors per condition. The three main effects were statistically significant: Alerting, $F(1, 66) = 6.2$; $p < .01$; partial $\eta^2 = .09$; Orienting, $F(1, 66) = 355$; $p < .001$; partial $\eta^2 = .84$; and Executive Attention, $F(1, 66) = 342$; $p < .001$; partial $\eta^2 = .83$) for the RT analysis. Significant interactions were found between Alerting and Orienting, $F(1, 66) = 5.2$; $p < .05$; partial $\eta^2 = .07$, and Orienting and Executive Attention, $F(1, 66) = 18.8$; $p < .001$; partial $\eta^2 = .22$). For the ANOVA with error percentage, the only statistically significant effect was that of Executive Attention, $F(1, 66) = 26.7$; $p < .001$; partial $\eta^2 = .28$. Scores for each of the attention networks were calculated for each participant according to the subtractions described in Figure 2 using median RTs. Since the main effect of Executive Attention was significant in the accuracy ANOVA, we also calculated the score for this network using the percentage of errors.

Correlation Analysis

Pearson's unilateral correlations between the attention network scores and temperament measures are given in Table 2. Only temperamental factors with $\alpha > 0.50$ were included in the analysis. Correlations between the attention network scores and temperamental factors with all the school competence and social adjustment measures are given in Table 3. Finally, correlations among school competence and social status measures are shown in Table 4.

Regressions

Three dependent measures showed significant correlation with both executive attention and EC: grades in mathematics, mean of all grades, and the measure of Unsocial (see Table 3). To examine the unique contribution of these two aspects of self-regulation on the variance of these dependent measures, we conducted stepwise multiple regression analysis, controlling for covariance between independent measures. These analyses indicated that both parent-reported EC ($\beta = .47$; $p < .01$) and the executive attention score as measured by RT ($\beta = -.24$; $p = .05$) were significant predictors of the grade in mathematics (R^2 of the model: .34). However, the parent-reported EC ($\beta = .62$; $p < .05$) was uniquely related to the average of all grades (R^2 of the model: .47). Likewise, parent-reported EC was the unique significant predictor ($\beta = -.39$; $p < .05$) of Unsocial in the regression model (R^2 of the model: .15).

Mediational Analysis

We argued that aspects of self-regulation might mediate the relationship between social adjustment and schooling outcomes. To test this hypothesis, we carried out mediational analysis for those social and self-regulation variables that were intercorrelated with the average of grades and the average of schooling skills. The first mediational analysis showed that Unsocial behavior significantly predicted EC ($\beta = -.37$), as well as the average of grades ($\beta = -.28$). EC also significantly predicted the average of grades ($\beta = .6$). However, when EC was entered in the regression equation together with Unsocial, EC still significantly predicted the average of grades ($\beta = .7$), whereas Unsocial no longer significantly predicted the average of grades ($\beta = -.08$). This indicates that parent-reported EC mediates the relationship between higher levels of unsocial behavior and poor academic achievement at school (Figure 3a). Subsequent mediational analysis tested whether the relation between Unsocial and the average of all Schooling Skills was

Table 2
Correlations Between Attention and Temperament Measures

		Parent-Reported EATQ-r			*Self-Reported EATQ-r*		
		EC_P	AF_P	NA_P	EC_S	E/S_S	NA_S
ANT scores	Executive Attention RT	.25*	-.06	.09	-.01	.004	-.14
	Executive Attention ERR	-.21	.07	.17	-.12	-.24*	.002
	Alerting RT	-.06	-.08	-.01	.32*	.16	-.28*
	Orienting RT	.002	-.027	-.006	.04	-.18	-.18

Note. Suffix "p" indicates parent-reported, suffix "s" indicates self-reported. AF = Affiliation; EC = Effortful Control; E/S = Extraversion/Surgency; NA = Negative affect. Significance level: *$p < .05$.

Table 3

Correlation Between Attention and Temperament Measures and Measures of School Competence

		Grades		*Schooling Skills*					*Social Status*							
		Math	*Average of All*	*Rule following*	*Student-role understanding*	*Sociability*	*Tolerance to Frustration*	*Average of All*	*Good to work with*	*No good to work with*	*Good for free time*	*No good for free time*	*Appreciated*	*Unsocial*	*Rejected*	*Mean of Social Appreciation*
Attention	EX_{TR}	-.28*	-.17	-.07	.07	.16	-.06	.03	-.09	.18	.10	.25*	-.04	.30*	.19	-.04
(ANT	EX_{ER}	-.23*	-.28*	.13	-.04	-.13	-.02	-.02	-.14	.02	.001	.07	-.05	-.10	.06	.02
scores)	AL_{TR}	-.07	-.05	.03	.03	.25*	.15	.15	.14	.04	.03	-.04	.01	-.09	.04	-.13
	OR_{TR}	.13	.09	-.09	-.22*	-.05	-.16	-.17	.02	.04	.08	.07	.03	-.12	.10	.06
EATQ-r	EC_S	.30**	.32**	.37**	.84**	.29**	.34**	.45**	.14	-.09	-.14	-.18	.20	-.12	-.10	-.03
self	E/S_S	-.09	-.18	-.15	.03	.10	-.04	-.02	-.11	-.004	.07	.05	-.10	.26*	-.04	-.17
report	NA_S	-.14	-.16	-.32**	-.33**	-.27*	-.29**	-.39**	.08	-.06	.12	-.07	-.05	.23	-.12	.29*
EATQ-r	EC_P	.58**	.65**	.39**	.44**	.32*	.29*	.45**	.23	-.01	-.30	-.21	.45**	-.37*	-.06	.33*
parent	AF_P	.32*	.21	.06	.21	.15	.04	.15	.37*	-.15	.03	-.15	.38*	-.12	.05	.03
report	NA_P	-.28*	-.30*	-.24*	-.23*	-.29*	-.09	-.27*	-.35*	.29	.15	.50**	-.26	.26	.33*	-.40*

Note. Suffix "p" indicates parent reported; suffix "s" indicates self reported. AF = Affiliation; AL = Alerting; EC = Effortful Control; E/S = Extraversion/Surgency; EX = Executive attention; OR = Orienting; NA = Negative affect. Significance levels: **$p < .01$. *$p < .05$.

Table 4

Correlation Among Measures of School Competence

		Grades		*Schooling Skills*					*Social Status*						
		Math	*Average of All*	*Rule Following*	*Student-role Understanding*	*Sociability*	*Tolerance to Frustration*	*Average of All*	*Good to work with*	*No good to work with*	*Good for free time*	*No good for free time*	*Appreciated*	*Unsocial*	*Rejected*
Grades	Math	—													
	All	.87**	—												
Schooling	RF	.38**	.48**	—											
skills	SrU	.24*	.38**	.71**	—										
	SO	.004	.20*	.37**	.57**	—									
	TF	.29*	.28*	.49**	.40**	.34**	—								
	All	.29*	.43*	.82**	.85**	.72**	.73**	—							
Social	GW	.48**	.50**	.29*	.21	.19	-.02	.21	—						
status	NGW	-.17	-.15	-.05	-.05	-.03	-.01	-.05	-.24	—					
	GFT	.18	.03	-.11	-.15	-.01	.02	-.08	.35**	-.21	—				
	NGFT	-.33*	-.37**	-.28*	-.21	-.20	-.12	-.26*	-.55**	.79**	-.02	—			
	AP	.39**	.46**	.19	.30*	.35*	.17	.32*	.53**	-.13	.28*	-.23	—		
	US	-.27*	-.28*	-.44**	-.19	-.07	-.30*	-.33*	-.25*	.10	.04	.26*	-.12	—	
	RJ	-.16	-.20	-.01	.01	-.05	-.10	-.04	-.32*	.72**	-.14	.79**	-.07	-.04	—
	mSA	.20	.29*	.08	.11	.08	-.08	.06	.38**	-.29*	.18	-.36**	.09	.07	-.37**

Significance levels: **$p < .01$. *$p < .05$

also mediated by parent-reported EC (Figure 3b) as well as the mediational role of EC in the relationship between social appreciation and schooling outcomes (Figure 4). EC was found to be a significant mediator of both the average of Schooling Skills and the average of all grades. Other mediational analysis were conducted with executive attention as the potential mediator between social measures and grades in mathematics, average of all grades, and average of schooling skills; these analyses yielded no significant mediational effects.

DISCUSSION

Attention and Schooling Outcomes

The executive attention score is indicative of the efficiency of brain mechanisms involved in conflict resolution and cognitive control (Posner & DiGirolamo, 1998). Individual variations in this score were related to academic achievement in general and more consistently to grades in mathematics. We also found a significant correlation between the executive attention score and parent-reported EC. As discussed earlier, the executive attention measure taps the efficiency of neurocognitive mechanisms important for resolving conflict among incongruent stimuli, such as detection of conflict and inhibition of both processing and responding to nonrelevant stimulation. EC refers to the efficiency with which self-regulatory abilities are used in both personal and interpersonal situations that require overcoming dominant but inappropriate responses. Our data showed that executive attention accounted for unique variance only when predicting grades in mathematics. Prior studies carried out with younger children have shown that various measures of executive function predict competence in arithmetic tasks (Blair & Razza, 2007; Bull & Scerif, 2001; Espy et al., 2004). In a study with kindergarteners, a cognitive measure of inhibitory control accounted for unique variance, independent from teacher's reports of EC, in predicting math abilities (Blair & Razza, 2007). Lateral frontal regions of the brain considered part of the executive attention network are activated by marker tasks of general intelligence (Duncan et al., 2000). In our view, efficiency of this brain system results in more successful acquisition and application of knowledge taught at school, especially in those subjects involving complex reasoning such as mathematics.

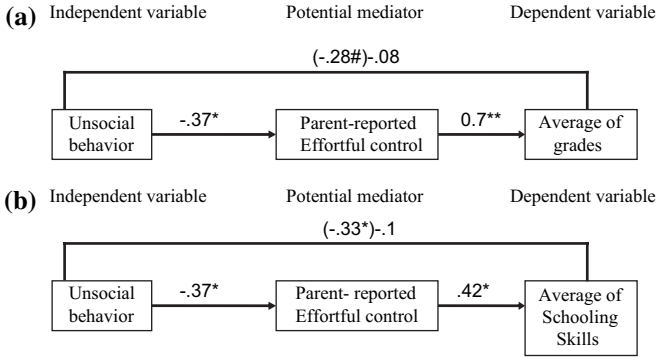

Fig. 3. Effortful Control as mediator of the effect of unsocial behavior on school competence. (a) Model predicting average of grades. (b) Model predicting average scores of Schooling Skills. Numbers are β values. Values in parenthesis show βs when the independent variable is regressed alone on the dependent variable. These values are followed by βs when both the independent variable and the potential mediator are regressed on the dependent variable. Significance levels: *** $p < .001$; ** $p < .01$; * $p < .05$; # $p < .06$.

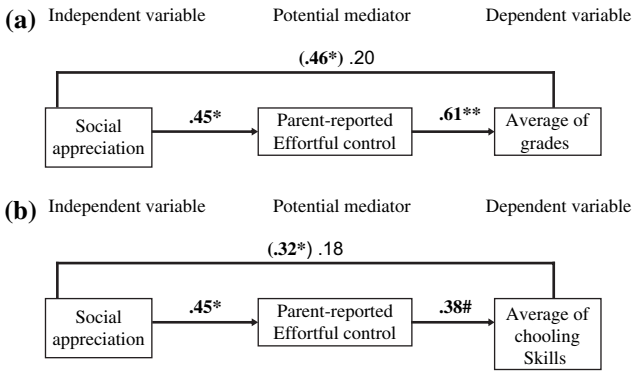

Fig. 4. Effortful Control as mediator of the effect of social appreciation behavior on school competence. (a) Model predicting average of grades. (b) Model predicting average scores of Schooling Skills. Numbers are β values. Values in parenthesis show βs when the independent variable is regressed alone on the dependent variable. These values are followed by βs when both the independent variable and the potential mediator are regressed on the dependent variable. Significance levels: ***$p < .001$; **$p < .01$; *$p < .05$; #$p < .06$.

Larger interference scores, and hence poorer executive attention efficiency, was also related to peer reports of unsocial behavior as well as to nominations for being someone "not good to spend free time with." This relationship is also consistent with the role given to the executive attention network in Posner's model. One of the main nodes of this network, the ACC, is involved in controlling cognitive as well as affectively relevant information. The strong connections between the ventral division of the ACC and subcortical limbic structures such as the amygdala are likely to implement a circuitry for the control of emotion (Posner, Sheese, Odludas, & Tang, 2006). Larger rates of unsocial behavior together with larger interference scores in the ANT indicate less efficiency of this circuitry in exercising control over negative emotionality, likely leading to social maladjustment and rejection by peers.

The scores of the alerting and orienting networks show a much less clear pattern of associations with schooling outcomes than executive attention. The correlation between the alerting score and socialization might indicate that greater levels of responsiveness to stimulation leads to better processing of socially relevant cues from others, thereby

enhancing responsiveness to such cues. However, the correlation between orienting and the SrU scale is more puzzling. Understanding this association would require replication and further investigation.

Imaging of brain activation during performance of the ANT has shown that performance of this task differentially activates the anatomical networks related to alerting, orienting, and executive attention (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Moreover, the extent of activation of these networks appears to relate to performance of the task, which in turn relates to individual variation in particular genes involved in brain neurophysiology (Fan, Fossella, Sommer, Wu, & Posner, 2003; Fossella et al., 2001). In future studies, it would be desirable to include measures of brain function during performance of cognitive tasks to test the connection between activation of the brain network and behavioral regulation and achievement at school.

Temperamental Contributions to Social and Academic Outcomes

Temperamental systems of negative emotionality show a strong association with poorer schooling skills that is consistent across self and parent reports. Moreover, parent-reported negative affectivity is associated with low academic performance and increased social rejection in school. However, both self- and parent-reported temperamental EC is positively related to all measures of schooling skills and academic achievement, and parent-reported EC is also positively associated with social appreciation and negatively with unsocial behavior (Table 3).

The variety of measures used in our study allows for a deeper understanding of how temperament may influence school outcomes. Those children with higher reactive negative emotionality have more trouble following rules, understanding their role as students, socializing with peers, and tolerating frustration, and therefore might be experiencing greater difficulties adapting to the classroom setting. In turn, failure to use these skills likely results in behavior disruptive to the classroom routine, thus affecting both achievement and social acceptance, and potentially leading to increased discouragement, frustration, and avoidance of potential sources of learning. However, the positive association between individual differences in self-regulatory systems such EC and social and academic outcomes likely represent the influence of attentional control, persistence and motivation in the learning context (Martin, Drew, Gaddis, & Moseley, 1988; Rothbart & Hwang, 2005; Rothbart & Jones, 1998). Moreover, EC might provide the regulatory capacity needed to detect feelings of distress in oneself and others and link them to actions and moral values (Kochanska & Aksan, 2006). Thus, children with higher EC scores are more able to use their self-regulatory capabilities to comply with the demands of teachers and peers in the classroom, thus increasing their social acceptance and their opportunities to learn (Rothbart & Jones, 1998).

Additionally, better adjusted children are the ones obtaining better grades at school and showing better scores in skills important for positive schooling (Table 4). This pattern of associations is consistent with prior studies establishing that socioemotional competence contributes to adequate academic progress during childhood (Ladd, Herald, & Kochel, 2006). However, mediational analyses indicate that the relationship between social maladjustment and poorer schooling outcomes is mediated by EC (Figures 2 and 3). Although other studies have proposed that the development of positive social relationships in the school is the primary factor promoting school competence (Mashburn & Pianta, 2006), our data suggest that individual differences in temperamental systems of self-regulation are central to understanding the relation between social adjustment in the school and students' performance.

Implications for Education

Our results point to the importance of understanding students' temperament by parents and educators to promote their adaptation to the classroom. Increased teacher's awareness of how students' temperament relates to their responses to the social and academic challenges is likely to reduce teacher's negative reactions and promote feelings of support, which in turn have the potential to reduce conflict and encourage the use of more appropriate coping strategies by the students (Pullis, 1985).

Emphasizing the mediating role of self-regulatory processes also offers guidance for designing interventions to improve school readiness by enhancing cognitive and temperamental control systems. In the recent years, there have been several efforts to design programs aimed to promote executive control abilities in normally developing preschoolers and first graders (Diamond, Barnett, Thomas, & Munro, 2007; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005) and children suffering from attention-related pathologies (Klingberg et al., 2005). Although these efforts to train aspects of self-regulation show very promising results, they have mainly focused in the training and testing effects at the neurocognitive level. Further research would be needed to examine whether the beneficial effects of these interventions also affect temperament and academic performance and transfer to abilities relevant for schooling competence such socioemotional regulation.

Several developmental studies have shown a progressive development of self-regulatory functions up to late adolescence, with the greater development occurring during early childhood (Rothbart & Rueda, 2005; Rueda et al., 2004). The association between either performance in cognitive tasks or reports of children's EC and achievement, and

socioemotional regulation has been found from early childhood (Blair, 2002; McClelland et al., 2007). However, assessing this relationship in cross-sectional and/or longitudinal studies along the periods of major development of self-regulation would inform about the influence of the maturation of systems of self-regulation on the control of behavior required for school competence, as well as the developmental periods in which interventions to foster regulatory capacities have the greater impact in children's social and academic competence.

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NOTE

1 The modified ANT (Callejas, Lupianez, & Tudela, 2004) is structurally similar to the original ANT, except that it presents the alerting and orienting cues in separate displays in order to be able to assess interactions between these two networks.

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